Fishery Data Series No. 97-21

Location of Lake Trout Spawning Areas in Harding Lake, Alaska

by
Tim Viavant

September 1997

Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 97-21

LOCATION OF LAKE TROUT SPAWNING AREAS IN HARDING LAKE, ALASKA

by

Tim Viavant
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

September 1997

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-12, Job No. E-3-1(b).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or a group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

Tim Viavant
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599,USA

This document should be cited as:
Viavant, T. 1997. Location of lake trout spawning areas in Harding Lake, Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 97-21, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICIES

ABSTRACT

Lake trout *Salvelinus namaycush* were captured in June and July, 1996, from Harding Lake using sinking, multifilament gillnets. Twelve fish (FL $\geq$ 550 mm) were captured and fitted with high power, high frequency (149 mHz), externally mounted radio tags and released. The 12 fish were radio-tracked once during July and August and two to three times per week from September 9 through October 3 (spawning season) to assess potential spawning locations. Spawning aggregations were then located visually and the number of fish present counted. Two spawning locations were positively identified by visual confirmation of 10 or more fish at the same location on more than three occasions. A possible third spawning location was identified. Radio-tracked fish were located at this site on seven different occasions but only two additional fish were visually observed on each of two different occasions.

Key words: lake trout, *Salvelinus namaycush*, spawning locations, radiotelemetry, Harding Lake.

INTRODUCTION

Harding Lake is a large lake located 72 km (by road) south of Fairbanks, just off the Richardson Highway. The lake has a surface area of 1,000 ha, and a maximum depth of 42 m with two small inlet streams and no outlet (Figure 1). Substrates at Harding Lake are mostly sand or fine silt at depths of 3 m or less, and entirely fine silt at depths greater than 3 m (Nakao 1980). There are extensive areas of small gravel mixed with sand, and a few limited areas of small cobble mixed with sand and gravel. There are also a few limited areas of submergent vegetation at depths of 2.5 to 6 m, but all emergent vegetation at the lake consists of dense beds of grasses, mostly growing in water less than 0.5 m deep.

Harding Lake supports a fishery that averaged an estimated 4,794 angler-days per year between 1986 and 1995 and increased from estimates of around 5,000 angler-days per year between 1990 and 1994 to an estimated 6,743 angler-days in 1995 (Mills 1987-1994, Howe et al. 1995-1996). Most angler effort is directed at northern pike *Esox lucius* but estimates of lake trout *Salvelinus namaycush* catch and harvest from 1990 to 1995 have averaged 305 and 127 fish per year, respectively (Mills 1991-1994, Howe et al. 1995-1996).

Lake trout were first introduced to Harding Lake in 1939 (Doxey 1991). A number of other introductions of lake trout or fertilized lake trout eggs were also made into Harding Lake between 1963 and 1967 (Doxey 1991). Since then, lake trout have been introduced into Harding Lake only one other time, when approximately 71,000 fingerlings were stocked in 1990 (Clark et al. 1991). There is no definitive evidence that lake trout in Harding Lake were reproducing naturally until the early 1980s, when a number of fish were captured that, due to their ages, could only have resulted from natural spawning by native or previously stocked fish (Doxey 1991).

The population of lake trout in Harding Lake has never been estimated. Catch per unit effort (CPUE) data for lake trout has been extremely low during every assessment effort at Harding Lake when compared to similar Alaskan lakes with native lake trout populations. The average catch of lake trout for a 24 h set of a monofilament, variable mesh, experimental gillnet in Harding Lake was under 0.23 fish per net-night over 253 net-nights (0.0096 fish per net-hour) between 1987 and 1992 (Burr 1993). Capture rates for lake trout from north slope lakes using multifilament, single mesh gillnets range from a low of 0.25 fish per net-hour in Gailbraith Lake to 7.38 per net-hour at Nanushuk Lake (Burr 1995). These capture rates are not directly

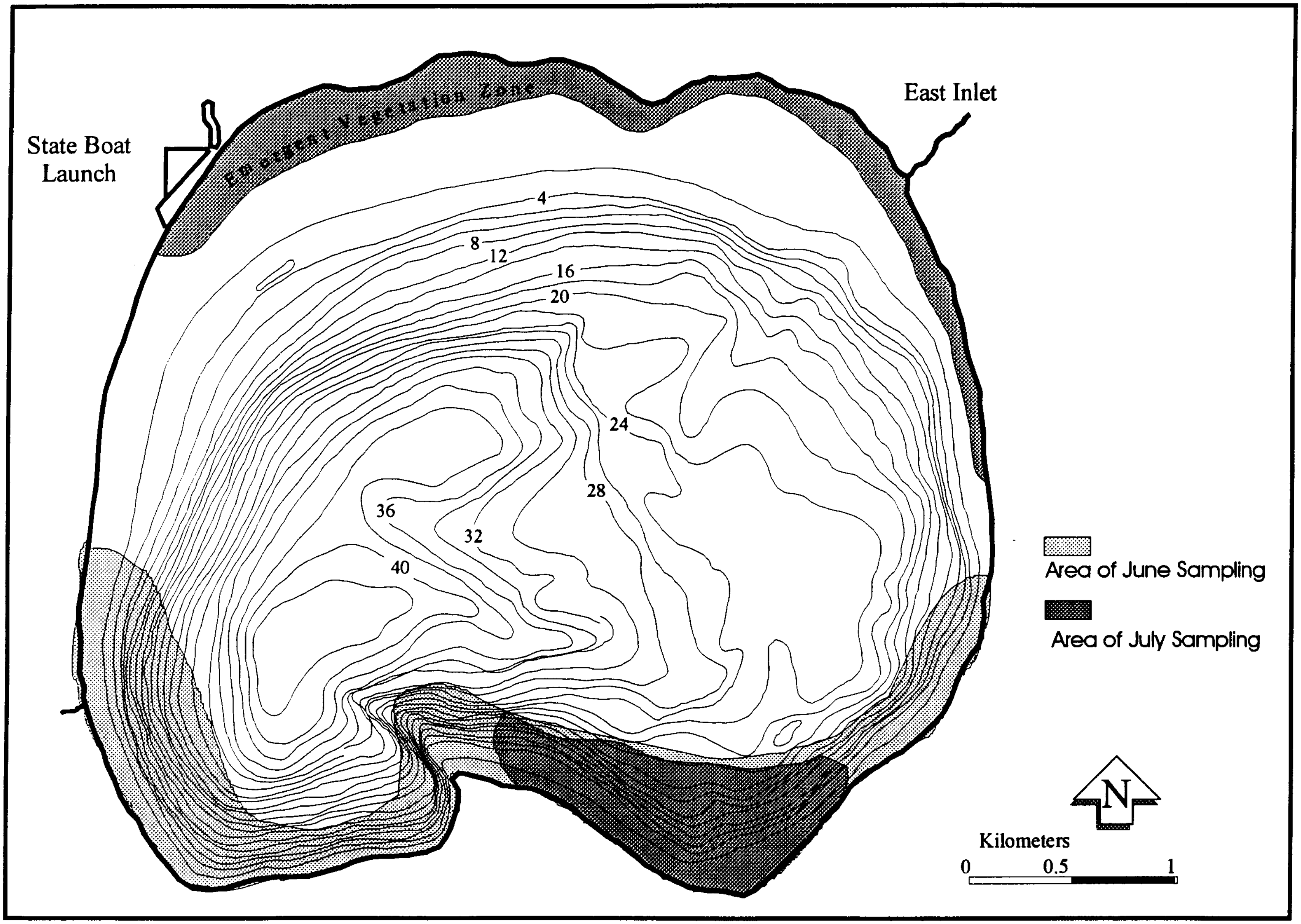


Figure 1.-Map of Harding Lake showing lake trout sampling areas during June and July, 1996.

comparable, because of the different gear types used, but they do indicate low lake trout density in Harding Lake. The low CPUE for lake trout in Harding Lake, combined with the small number estimated to have been caught or harvested in the recreational fishery, indicate that the population is relatively small, particularly for a lake of the size of Harding Lake.

Many factors influence the size of a lake trout population. This includes: prey availability, intra and inter specific competition, predation and spawning habitat. There is a very limited amount of suitable lake trout spawning habitat at Harding Lake and egg survival to hatching is probably very low. This is likely to be the major factor limiting the lake trout population in Harding Lake. Lake trout eggs have been found to have a very low survival rate to hatching (less than 2%) due to egg predation, particularly on substrates where eggs are left exposed (Wagner 1992). Lake trout eggs have been shown to be preyed upon by slimy sculpin *Cottus cognatus*, burbot *Lota lota*, whitefish *Prosopium sp*., and lake trout themselves (Martin and Olver 1980), all of which are present in Harding Lake.

Because of Harding Lake's proximity to Fairbanks and its popularity as an angling site, it could be beneficial to enhance the size of the lake trout population for increased catch and harvest success. Previous attempts at stocking small fish in Harding Lake have not resulted in increased catches or harvests that justified the costs of stocking (Doxey 1991, Viavant 1992). Alternative methods of enhancement for lake trout include increasing the quantity of available spawning habitat, stocking fertilized lake trout eggs, or both. Fertilized eggs could be stocked directly onto man-made cobble reefs, or fertilized eggs could be hatched in artificial incubation substrates placed over existing spawning sites or man-made cobble reefs. Hatching success rates of over 70% have been shown for lake trout eggs hatched in artificial incubation substrates in Lake Superior (Swanson 1982) and an average hatching rate of 43% was found using similar methods at Donnelly Lake in the Alaska Range (Viavant 1996).

Several studies have found considerable evidence that lake trout show a high degree of fidelity in returning to their natal reef to spawn (Eschmeyer 1955, Martin 1957, Loftus 1958, Rahrer 1968, Swanson 1974), and that lake trout imprint on the reef on which they emerged from very early in life (Horrall 1981). Because of this, the success of future efforts to enhance egg survival of resident lake trout by increasing the quantity of spawning habitat would depend on knowing the location of an existing spawning area. The long term success of using artificial spawning substrates planted with eggs taken from a different location to create new spawning sites would also benefit by knowing the location currently used by resident lake trout for spawning. With that in mind, the objective of this study was to locate at least one spawning area used by lake trout in Harding Lake.

METHODS

Potential lake trout spawning sites were located in Harding Lake by radio-tagging a small number of adult fish during the summer and then locating these fish during the spawning season. Lake trout were captured during June 4-5 and July 9-17 using sinking, multifilament, 2 m x 38 m gillnets. Sampling in June occurred during 0900 to 1700 hrs and was done throughout the south half of the lake around the 10 to 15 m depth contours (Figure 1). Sampling in July was done during late 1800 to 2400 hrs and effort was concentrated in the area of the lake that produced the best catches during June sampling (Figure 1). Nets were fished in pairs of two tied end to end.

Three sets of two nets each were fished at one time. This allowed each set to be checked every 40 min to minimize capture mortality.

Fish were measured, tagged, and released as soon as possible after capture. All fish were tagged with a Floy tag, and 12 fish $\geq$ 550 mm fork length (FL) were tagged with an externally mounted, high frequency (149 mHz) radio tag manufactured by Lotek (model FRT10). Each radio tag weighed 70 g in air and was 25 mm in diameter and 70 mm in length; the tag antenna was 44 cm long. Fish 550 mm FL and greater were of sufficient size (at least 2,500 g) to be mature and thus likely to spawn in September. Radio-tags were attached by threading a thin plastic-coated cable through the cartilage above the spine just below the dorsal fin. This cable was threaded through the tag on one side of the fish and through a plastic backing plate on the other side of the fish. A piece of 2 mm neoprene padding was threaded between the fish and both the tag and the backing plate on each side of the fish. All radio-tagged fish were held for 15 min prior to release to evaluate their condition after tagging.

Radio-tagged fish were located by traveling the 10 m depth contour around the perimeter of the lake in a boat at low speed with the receiver in scan mode using a 4 m beam antennae (Telonics). When signals were picked up, a hand-held Yagi antennae was used for improved directional detection. Fish were then located to within a 50 m radius by switching to a small hand-held H antennae. On July 18 and August 20 fish were radio-tracked between 0800 and 1700 hrs. Beginning on September 10 (the beginning of spawning season), radio-tagged fish were tracked between 2100 and 0300 hrs. During the spawning season, radio-tagged fish were located two or three times weekly until October 4, when spawning had apparently ceased. All fish locations and spawning locations were determined by and recorded as GPS coordinates.

Beginning on September 10, each time a radio-tagged fish was located in water less than 4 m deep, the approximate location of the fish was determined using radio telemetry and then the area was searched visually using 500,000 candle power search lights. A location was considered a spawning site if more than two fish were located visually at the same location on more than two occasions. On September 20, fish were captured on a spawning site using a single, 5 min gillnet set to examine fish. Fish captured on spawning beds were categorized as "ripe" (expression of gametes) or "green" (no evidence of milt or eggs upon handling) (see Appendix A). These fish were measured, sexed, checked for spawning condition, and released immediately. Fish incidentally killed during capture were examined for sexual development and categorized as "mature" or "immature" after criteria given in Sharp and Bernard (1988).

RESULTS AND DISCUSSION

CAPTURE RATES

A total of 22 lake trout were captured in June and July. Fish ranged in length from 480 to 860 mm (Appendix A). The capture rate (CPUE) during June averaged 0.017 fish per net-hour. Capture rates during July, averaged 0.15 fish per net-hour. The higher CPUE during July could have been related to effort occurring during evening rather than during daylight. Fish may also have been more deeply dispersed during July than in June, since during June sampling the lake was essentially iso-thermal, and in July the lake was thermally stratified. It is also likely that CPUE was higher in July than June because the effort in June was dispersed over more area of the lake, and effort during July was concentrated in the area of the lake that had the highest fishing success during June sampling. There were two capture mortalities during the June and July sampling and one verified mortality of a radio-tagged fish in September.

FISH LOCATIONS

Of the 12 fish that were radio-tagged, only seven were ever located. No more than four fish were ever located on any one date and on several dates none were located. The fish that were never located may have died and sunk to the bottom in deep water or were alive but not in shallow enough water to be located on all tracking occasions. The radio-tags used in this study gave: 1) a detectable signal over 1 km from the tag when the tag was in water 10 m deep or less; 2) a detectable signal within a 100 m radius when the tag was 18 m deep; and, 3) no detectable signal when the tag was 25 m or deeper. One radio-tagged fish that died was located and the tag recovered. This fish had washed up along the north shore of the lake in September.

While it appeared that success in locating a radio-tagged fish at least once was greater with fish of larger size (FL > 650 mm; Table 1) there was no statistical difference ($t = 0.75$, $P > 0.10$).

Table 1.-Capture date, fork length of radio-tagged fish and success in finding the fish at least once.

Fish No.	Capture Date	Frequency (mHz)	Fork-Length	Located	Confirmed Mortality
1.	6/4/96	620	830	yes	no
2.	6/5/96	560	850	no	no
3.	6/5/96	640	665	yes	no
4.	7/9/96	420	651	no	no
5.	7/9/96	480	549	no	no
6.	7/10/96	460	611	no	no
7.	7/16/97	440	575	yes	yes
8.	7/16/96	520	860	yes	no
9.	7/16/96	660	812	yes	no
10.	7/17/96	540	568	no	no
11.	7/17/96	580	812	yes	no
12.	7/17/96	600	780	yes	no

Lake trout locations were determined either by radio telemetry or visually on spawning sites on nine different dates, two prior to spawning season and seven during spawning season (Appendix A). All locations appear graphically in Appendix B, and as GPS coordinates listed in Appendix C. Four lake trout were located by radio telemetry on July 18. Two of these fish had been tagged and released the previous day. One of these fish (tag 600) was very near the area that it had been captured, the other was about 1 km to the east, in the same area as another tagged fish that was captured in June (Appendix B1). The other fish located on July 18 was in the northwest quarter of the lake. Four fish were located on August 20. Three of these fish were the same fish that were located on July 18. Three of the four fish were located near the area sampled in July, and one was about 2 km west (Appendix B2).

SPAWNING SITE LOCATIONS

On September 10 two radio-tagged fish were located. One (tag 620) was about 0.5 km northwest of what was later designated as spawning site 1 and the other (tag 580) was near what was later designated as spawning site 2 (see Appendix B3). Neither fish was in shallow water and no additional fish were located visually. Surface water temperature was 10.6°C. On September 12, a radio-tagged fish (tag 640) was located near shore in water 2 m deep. Twenty to 30 additional fish were visually observed in the area and all were exhibiting prespawning behavior. Prespawning behavior was designated by fish congregating directly over the spawning substrates on the spawning grounds and swimming back and forth in close proximity to each other. Fish may nudge each others' sides, or swim under or over each other rubbing their dorsal and ventral surfaces (Martin and Olver 1980). This area was designated as spawning site number 1 (see Appendix B3). One radio-tagged fish (tag 440) was found dead along the north shore.

On September 17, a radio tagged fish (tag 580) was located in 1.5 m of water near the north shore (Appendix B4) and two additional fish were observed in the vicinity. This area was designated as spawning site 3, however due to the low numbers of fish observed it is only considered as a possible spawning site at this time. Two additional fish (tags 660 and 520) were located approximately 0.5-1.0 km southeast of tag 580. At spawning site number 1, 15-25 fish were observed, again exhibiting prespawning behavior. Tag 620 was located at spawning site number 2, and 20-30 fish were observed in the vicinity, exhibiting prespawning behavior (see Appendix B4).

On September 18, tag 660 was located about 0.5 km southeast of the boat launch (Appendix B5), however the signal was lost, probably as the fish moved into deeper water. Tag 520 was located about 0.75 km east of spawning site number 3; tag 620 was located about 0.5 km northwest of spawning site 1; and, tag 580 was located about 0.25 km north of spawning site 2 (Appendix B5). Twenty to 30 fish were again observed on spawning site 2.

On September 19, tag 660 was located at spawning site 3, and two additional fish were observed at the site (Appendix B6). Tags 620 and 520 were located about 1 km north of spawning site 1, and tag 580 was located near its location on the previous night (Appendix B6). Ten to 15 fish were observed at spawning site 1 and 20-30 fish were again observed at spawning site 2 (Appendix C). Using a 5 min gillnet site, 17 of the fish at spawning site 2 were captured to determine their spawning status. These fish ranged from 550 to 900 mm FL and 15 were males. All the males were ripe (easily expressing milt) and both females were green (vent swollen but not expressing eggs). This suggested that spawning had not yet occurred. Surface water temperature on September 19 had fallen to 9.0°C.

On September 20, tag 660 remained near spawning site 3 (Appendix B7). Foul weather prevented further tracking on this date. On September 24, tags 520, 660, 600 and 620 were located (Appendix B7), however none were near spawning sites. All three spawning sites were inspected on September 24, and again on October 1 and 3, however no fish were observed. It is thus concluded that spawning probably occurred between September 19 and September 24.

Spawning sites 1 and 2 were verified as such using the criteria chosen to determine a spawning site. Spawning site 3 was only considered a possible spawning site because no more than two fish were ever observed at any one time, which is not considered a spawning congregation. Spawning site 1 was in water 2.7 m deep, over silt substrates covered by fairly dense growth of a submergent macrophyte. Judging by the discreet area occupied by the spawning congregations of fish observed, the area used for spawning is quite small, probably around 3 m by 6 m. Spawning site 2 was in water 1.6 m deep, over substrates of angular rock, approximately 5 to 20 cm in diameter. Spawning site 2 was also very small, judging by the discreet location where fish were observed, and by the distribution of rocky substrate. This spawning area was approximately 2.5 m by 6 m.

CONCLUSIONS

In total, 30 to 50 fish were observed on two identified spawning sites. The majority of these fish were probably males, based on the sex ratio of those fish captured at spawning site 2 on September 19. Even assuming that these fish were all males, and that the sex ratio for all spawners is 1:1, observations made during this study would indicate that perhaps only 60 to 100 fish spawned this year at Harding Lake. Martin and Olver (1980) report lake trout spawning intermittently, particularly at northern latitudes, so it is possible that as few as 30 to 50% of the spawning age fish in Harding Lake are on spawning sites in any given year. It is also quite possible that not all of the spawning sites used by lake trout in Harding Lake were discovered in this study. While none of the research done on lake trout at Harding Lake provides abundance data, capture rates and the number of spawners observed indicate that the spawning stock of lake trout in Harding Lake is relatively small.

Judging by the size and quality of the spawning habitat, it would be relatively easy and inexpensive to substantially increase the amount of spawning habitat in Harding Lake. It is recommended that a spawning site of mixed cobble similar in size to spawning site 2 be created near spawning site 2. Such an artificially created site could be monitored during future spawning seasons to see if fish currently spawning in Harding Lake begin to spawn on newly created spawning habitat. In addition to monitoring for use by spawners currently in Harding Lake, fertilized lake trout eggs could be placed on the new spawning area, either directly, or in artificial incubation substrates. Since lake trout seem to imprint very early in life on the area they hatch from, this could establish a spawning stock using the newly created spawning habitat.

ACKNOWLEDGMENTS

I thank P. Houghton, M. Doxey, and C. Skaugstad for assistance in capturing and radio-tagging fish. Thanks to J. Burr and M. Evenson for help locating spawning areas. Thanks to M. Wallendorf for help in determining the number of potential spawners to radio-tag. I also thank the U.S. Fish and Wildlife Service for the funding of this project through the Federal Aid in Fish Restoration Act (16 U.S. C. 777-777K) under Project F-10-12, Job No. R-3-1(a).

LITERATURE CITED

Burr, J. M. 1993. Evaluations of introduced lake trout in the Tanana drainage, and estimation of mortality using maximum age analysis. Alaska Department of Fish and Game, Fisheries Data Series No. 93-27, Anchorage.

Burr, J. M. 1995. Lake trout studies in the AYK region, and burbot index of abundance in Gailbraith Lake, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-30, Anchorage.

LITERATURE CITED (Continued)

Clark, J. H., T. R. Viavant, C. Skaugstad, and T. R. McKinley. 1991. Growth, survival, and costs of rearing game fish in floating net-pens at Harding Lake, Alaska, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-2, Anchorage.

Doxey, M. 1991. A history of fisheries assessments and stocking programs in Harding Lake, Alaska, 1939-1989. Alaska Department of Fish and Game, Fishery Manuscript No. 91-2, Anchorage.

Eschmeyer, P. H. 1955. The reproduction of lake trout in southern Lake Superior. Transactions of the American Fisheries Society 84:47-74.

Horrall, R. 1981. Behavioral stock isolating mechanisms in Great Lakes fishes with special references to homing and site imprinting. Can. Journal of Fisheries and Aquatic Sciences. 38:1481-1496.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Howe, A. L., G. Fidler, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage.

Loftus, K. H. 1958. Studies on river spawning populations of lake trout in eastern Lake Superior. Transactions of the American Fisheries Society 87:259-277.

Martin, N. V. 1957. Reproduction of lake trout in Algonquin Park, Ontario. Transactions of the American Fisheries Society 86:231-244.

Martin, N. V, and C. H. Olver. 1980. The lake charr, Salvelinus namaycush. In E.K. Balon (Ed.) Charrs, Salmonid fishes of the genus Salvelinus. Dr. W. Junk, The Hague.

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

Nakao, K. 1980. Climatic changes in the interior Alaska. Report of the Alaskan paleolimnology research project, 1977/78/79. Faculty of Science, Hokkaido University, Hokkaido, Japan.

Rahrer, J. F. 1968. Movements of adult lake trout in Lake Superior. Transactions of the American Fisheries Society 97:481-484.

Sharp, D. and D. R. Bernard. 1988. Precision of estimated ages of lake trout (Salvelinus namaycush) from five structures. North American Journal of Fisheries Management 8:367-372.

LITERATURE CITED (Continued)

Swanson, B. L. 1974. Lake trout homing, migration, and mortality studies, Lake Superior. Wisconsin Dept. Nat. Resources Management Report 65. 22 pp.

Swanson, B. L. 1982. Artificial turf as a substrate for incubating lake trout eggs on reefs in Lake Superior. Progressive Fish Culturist. 44(2):109-111.

Viavant, T. V. 1992. Comparative abundance of resident and stocked species of fish in Harding lake, Alaska, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-9, Anchorage.

Viavant, T. V. 1996. Hatching success of fertilized lake trout eggs in artificial incubation substrates in Donnelly Lake, Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 96-42, Anchorage.

Wagener, W. C. 1992. Evaluation of lake trout egg plants in Michigan waters of Lakes Michigan and Huron. Michigan Department of Natural Resources Fisheries Research Report No. 1976. 15 pp.

APPENDIX A

Appendix A.-Lake trout gillnetted at Harding Lake, 1996.

Capture Date	Fork Length (mm)	Sex[a]	Tag No.	Tag Color	Radio-tag Frequency	Maturity[c]
6/4/96	830	u	64377	blue	149.620	u
6/5/96	850	u	64378	blue	149.560	u
6/6/96	665	u	64379	blue	149.640	u
7/9/96	549	u	64380	blue	149.480	u
7/9/96	651	u	64381	blue	149.420	u
7/10/96	611	u	64382	blue	149.460	u
7/16/96	812	u	64383	blue	149.660	u
7/16/96	860	u	64384	blue	149.520	u
7/16/96	527	u	64385	blue		u
7/16/96	527	u	64386	blue		u
7/16/97	575[b]	m	-	-	149.440	d
7/16/96	540	u	64387	blue		u
7/16/96	537[b]	f	-	-		i
7/17/96	812	u	64388	blue	149.580	u
7/17/96	532	u	64389	blue		u
7/17/96	780	u	64390	blue	149.600	u
7/17/96	556	u	64391	blue		u
7/17/96	568	u	64392	blue	149.540	u
7/17/96	480	u	64393	blue		u
7/16/96	562	u	64394	blue		u
7/18/96	528[b]	u	-	-		i
7/18/96	584	u	64395	blue		u
9/20/96	818	m	37650	green		r
9/20/96	761	m	37651	green		r
9/20/96	844	m	37652	green		r
9/20/96	863	m	64379	blue		r
9/20/96	825	m	37653	green		r
9/20/96	873	m	37654	green		r
9/20/96	629	m	37655	green		r
9/20/96	900	m	68002	blue		r
9/20/96	806	f	37656	green		g
9/20/96	820	m	37657	green		r

-continued-

Appendix A.-Page 2 of 2.

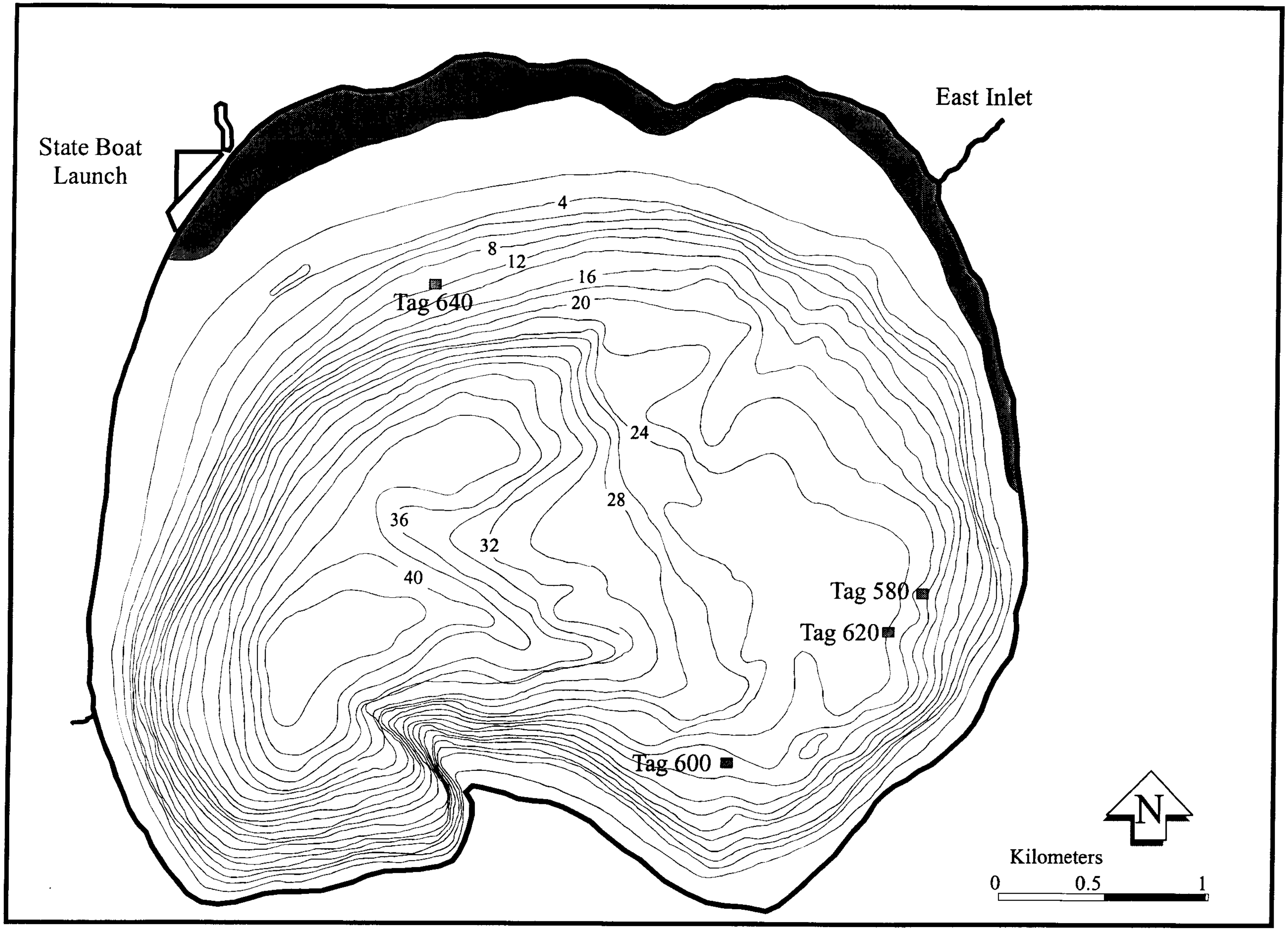
Capture Date	Fork Length (mm)	Sex[a]	Tag No.	Tag Color	Radio-tag Frequency	Maturity[c]
9/20/96	610	m	37658	green		r
9/20/96	839	m	37659	green		r
9/20/96	837	m	37660	green		r
9/20/96	775	f	37661	green		g
9/20/96	870	m	37662	green		r
9/20/96	550	m	37663	green		r
9/20/96	585	m	37664	green		r

[a] m = male, f = female, u = unknown.

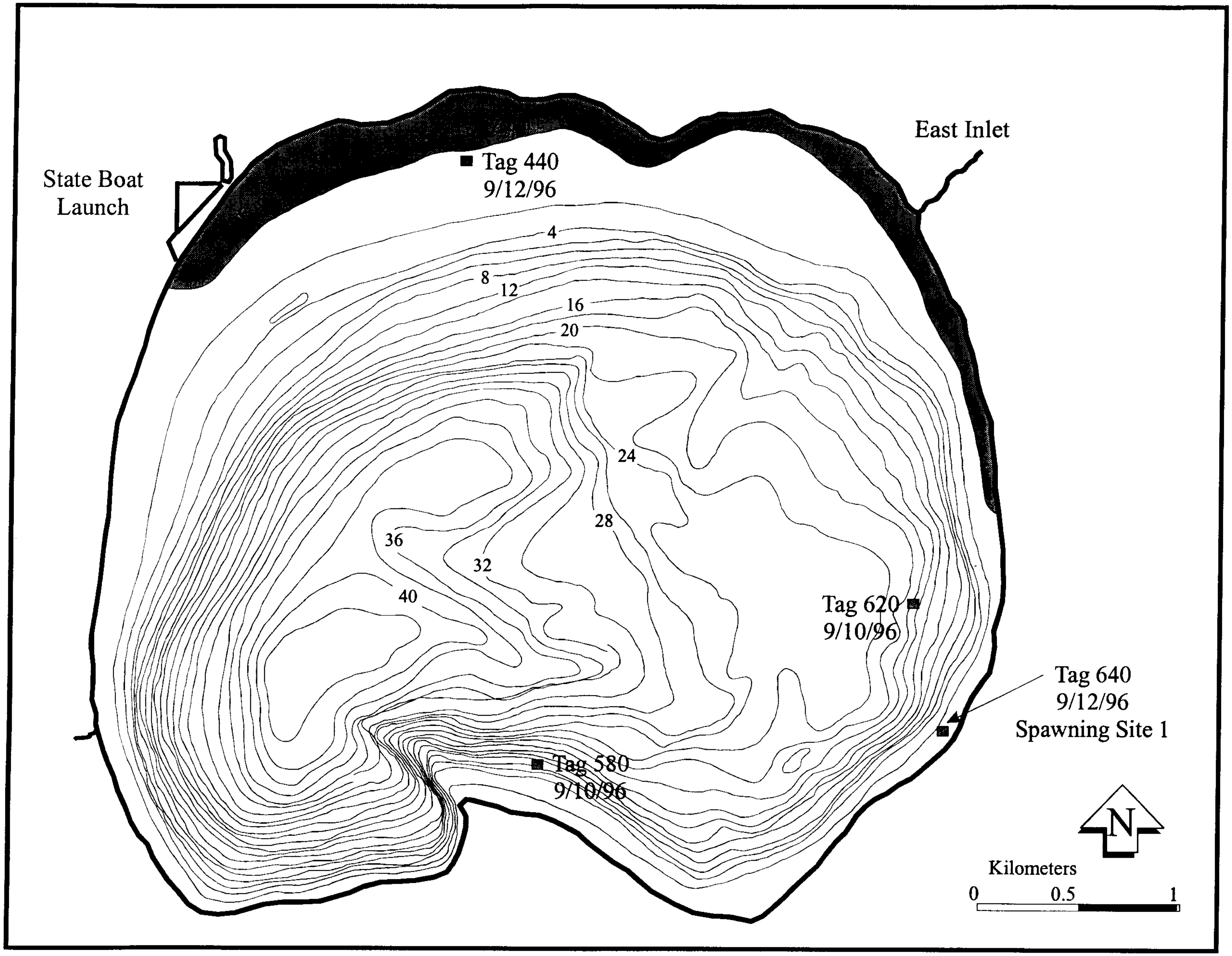
[b] fish mortality.

[c] r = ripe, g = green, u = unknown, i = immature.

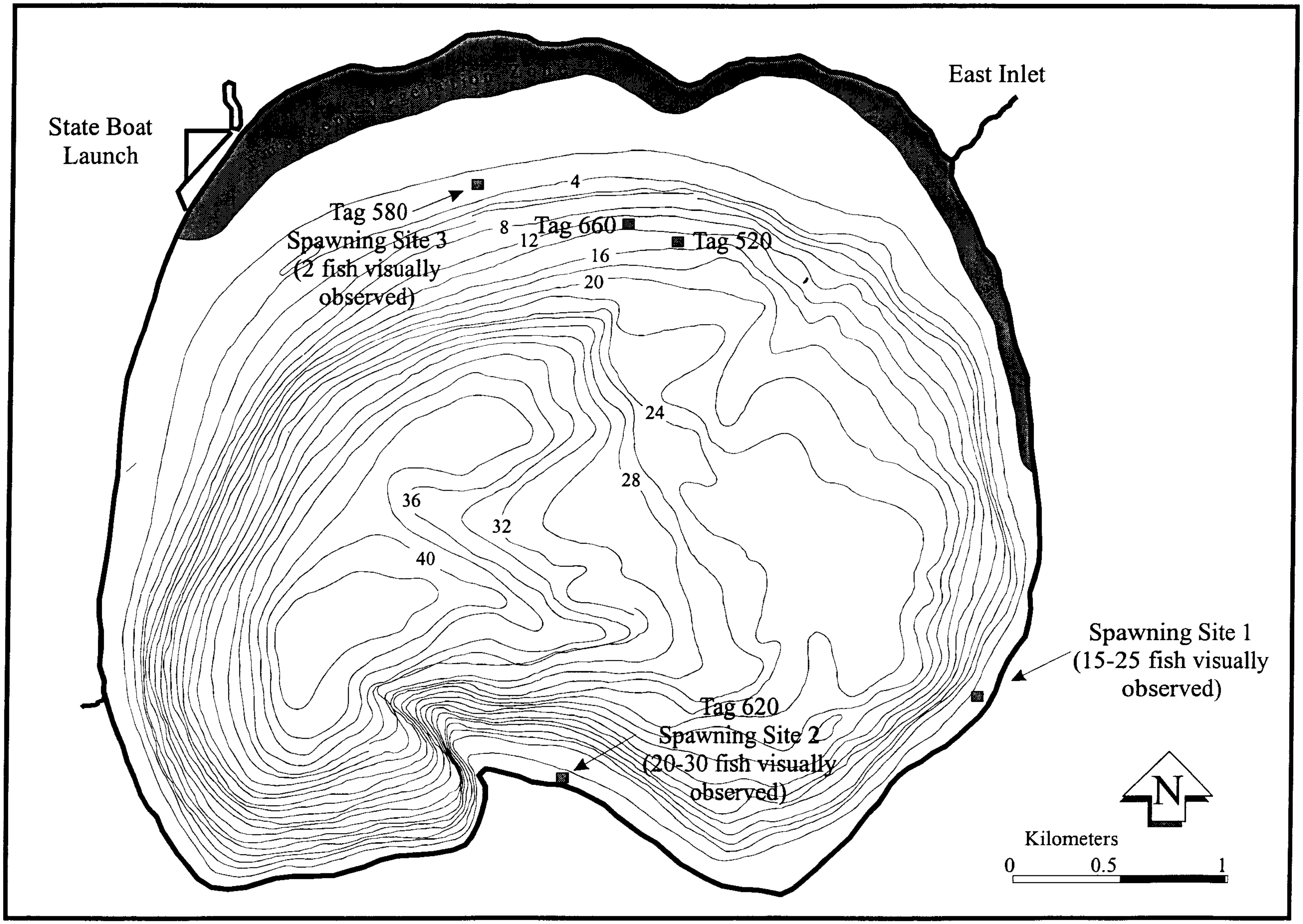
APPENDIX B



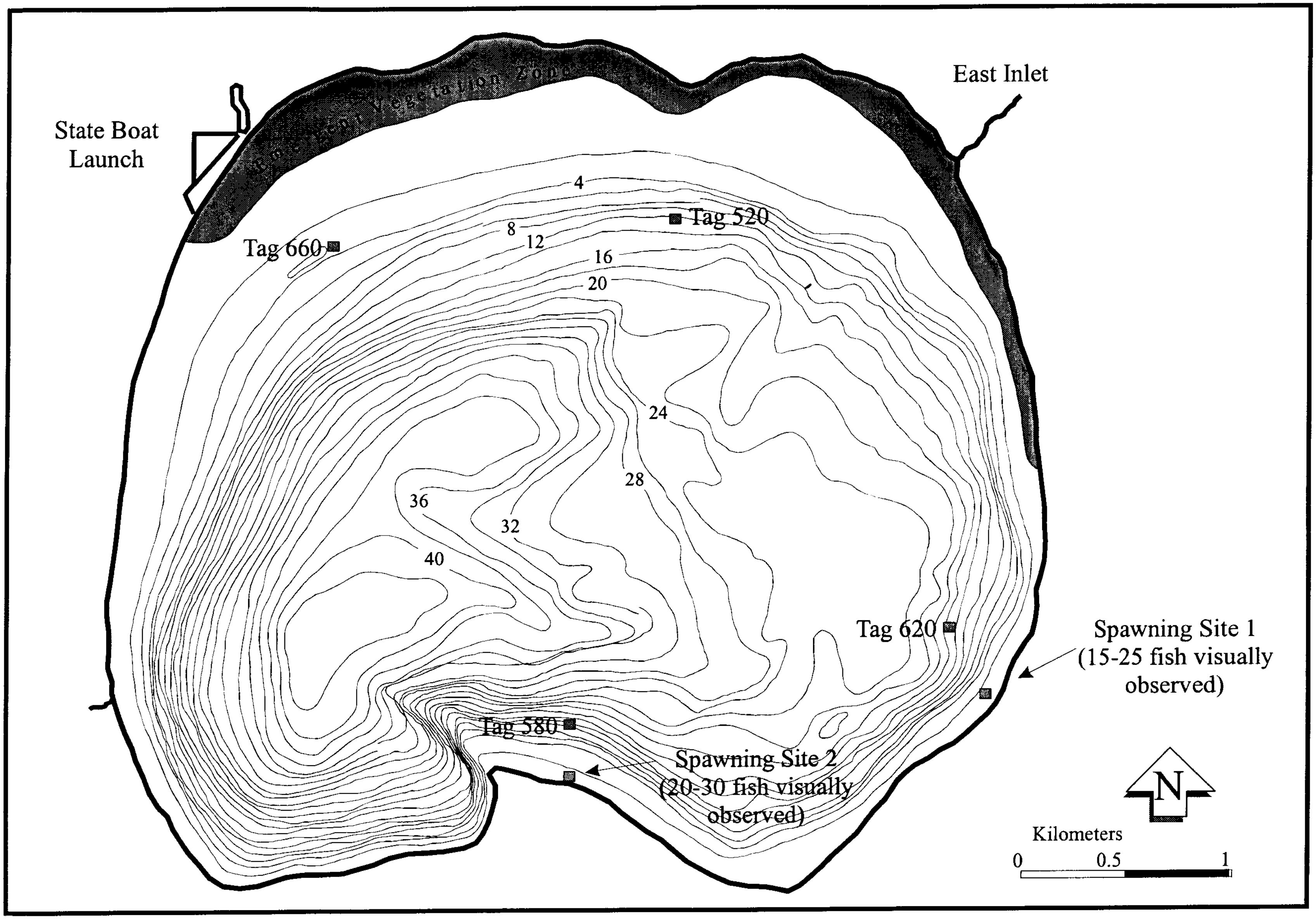
Appendix B1.-Map of Harding Lake showing locations of radio-tagged lake trout on July 18, 1996.



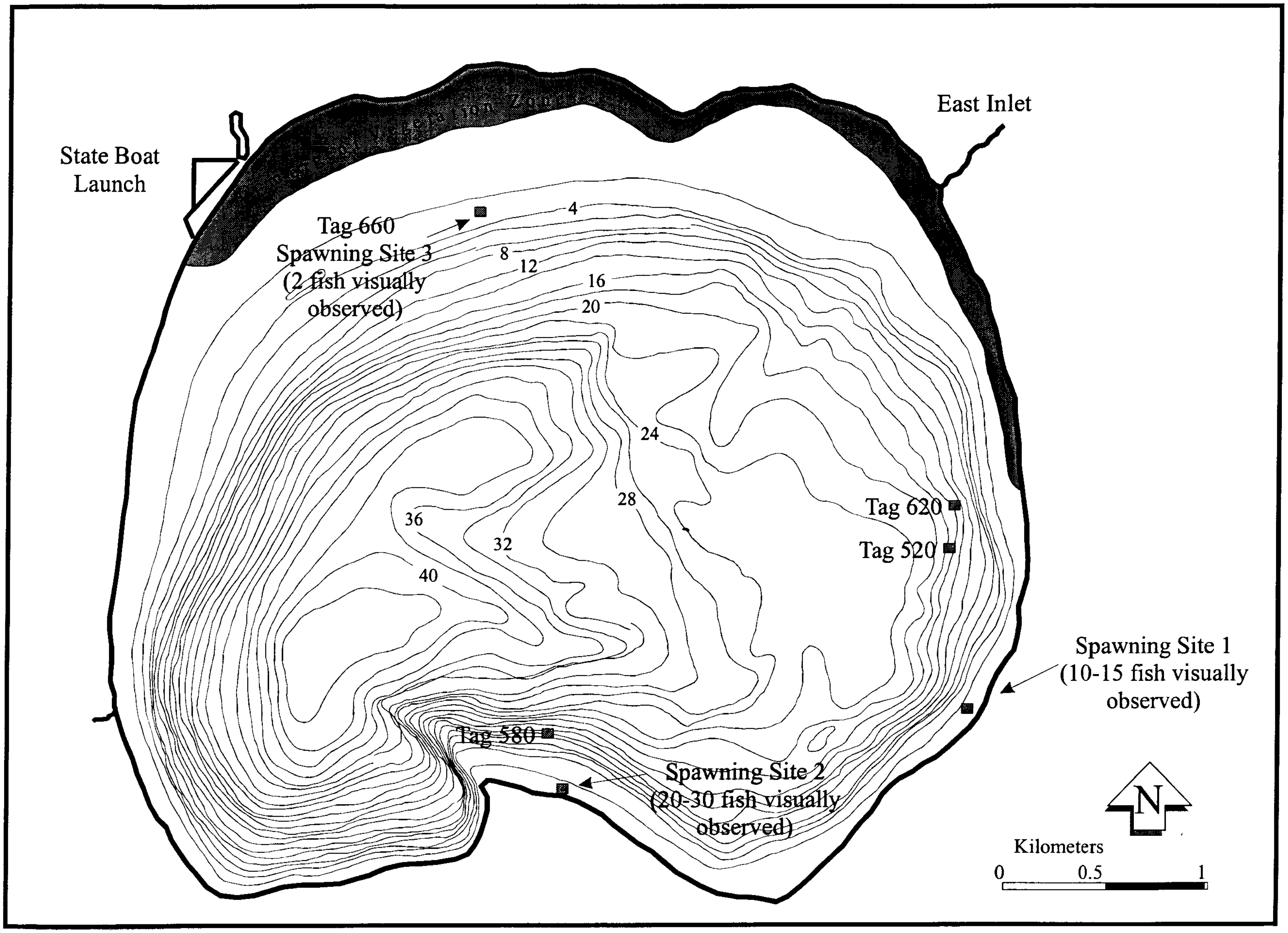
Appendix B3.-Map of Harding Lake showing locations of radio-tagged lake trout on September 10 and 12, 1996, and the location of spawning site 1.



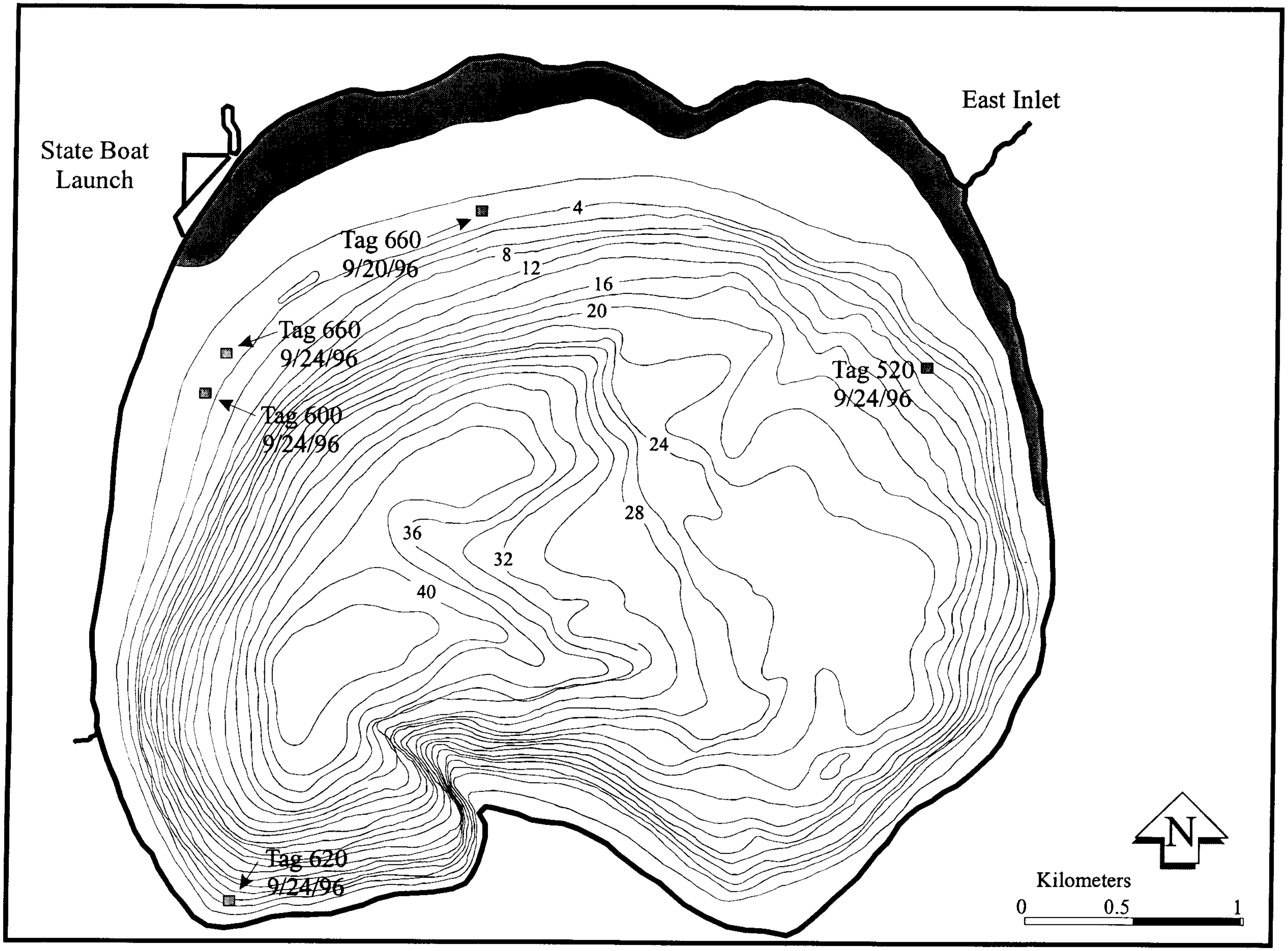
Appendix B4.-Map of Harding Lake showing locations of radio-tagged and visually observed lake trout on September 17, 1996.



Appendix B5.-Map of Harding Lake showing locations of radio-tagged and visually observed lake trout on September 18, 1996.



Appendix B6.-Map of Harding Lake showing locations of radio-tagged and visually observed lake trout on September 19, 1996.



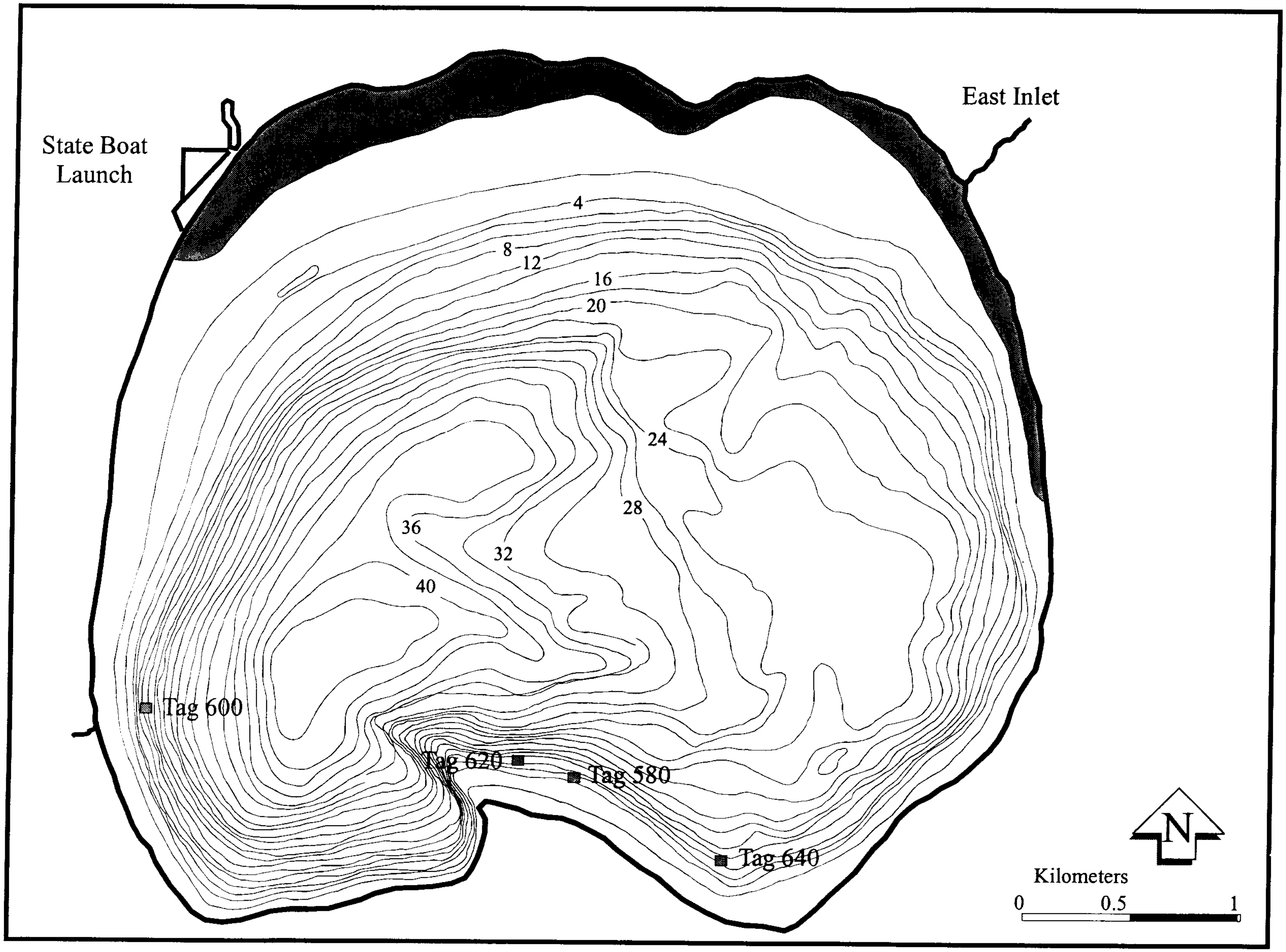
Appendix B7.-Map of Harding Lake showing locations of radio-tagged lake trout on September 20 and 24, 1996.

APPENDIX C

Appendix C.-Lake trout locations and spawning site locations in Harding Lake, 1996.

Date	Frequency (mHz)	GPS Latitude			GPS Longitude			Observed Visually?	Spawning Site?	Number Observed	Water Temperature (Degrees C)
7/18/96	149.580	64	25	26	146	49	49				
7/18/96	149.600	64	24	87	146	50	22				
7/18/96	149.620	64	25	22	146	49	51				
7/18/96	149.640	64	25	66	146	51	77				
8/20/96	149.580	64	24	81	146	51	21				
8/20/96	149.600	64	25	7	146	53	21				
8/20/96	149.620	64	24	87	146	51	50				
8/20/96	149.660	64	24	61	146	50	84				
9/10/96	149.580	64	24	91	146	51	18				10.8
9/10/96	149.620	64	25	22	146	49	33				
9/12/96	149.620	64	24	71	146	49	45	yes	yes	20 -30	10.6
9/12/96	149.440	64	26	18	146	51	62	yes/mort.		1	
9/17/96	149.580	64	25	96	146	51	54	yes	possible	2	10.0
9/17/96	149.520	64	25	83	146	50	42				
9/17/96	149.660	64	25	86	146	50	79				
9/17/96	149.620	64	24	68	146	51	43	yes	yes	20 - 30	10.0
9/17/96		64	24	71	146	49	45	yes	yes	15 - 25	10.0
9/18/96	149.660	64	25	90	146	52	8				
9/18/96	149.520	64	25	92	146	50	89				
9/18/96	149.620	64	25	17	146	49	28				
9/18/96	149.580	64	24	87	146	51	24				
9/18/96		64	24	68	146	51	43	yes	yes	20 - 30	9.3
9/18/96		64	24	71	146	49	45	yes	yes	15 - 25	9.5
9/19/96	149.660	64	25	91	146	51	23	yes	possible	2	
9/19/96	149.620	64	25	43	146	49	24				
9/19/96	149.520	64	25	32	146	49	36				

-continued-



Appendix B2.-Map of Harding Lake showing locations of radio-tagged lake trout on August 20, 1996.

Appendix C.-Page 2 of 2.

Date	Frequency (mHz)	GPS Latitude			GPS Longitude			Observed Visually?	Spawning Site?	Number Observed	Water Temperature (Degrees C)
9/19/96	149.580	64	24	84	146	51	25				
9/19/96		64	24	71	146	49	45	yes	yes	10 to 15	8.7
9/19/96		64	24	68	146	51	43	yes	yes	20 - 30	9.0
9/20/96	149.660	64	25	96	146	51	54				
9/24/96	149.520	64	25	57	146	49	47				
9/24/96	149.600	64	25	67	146	52	96				
9/24/96	149.620	64	24	71	146	52	88				
9/24/96	149.660	64	25	82	146	52	96				